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REMINDING AND MEMORY ORGANIZATION: AN INTRODUCTION TO MOPS. (U)

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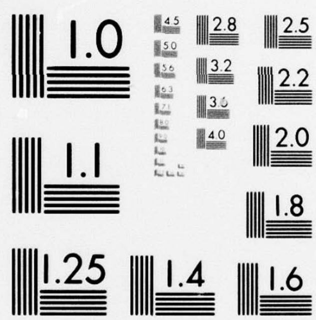

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Reminding and Memory Organization:
An Introduction to MOPs

December 1979

Research Report #170

Roger C. Schank

YALE UNIVERSITY
DEPARTMENT OF COMPUTER SCIENCE

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The organization of human memory is a central problem in Cognitive Science. Recent experimental work by Bower, Black, and Turner (1979), concerning some of the memory structures proposed in Schank and Abelson (1977), uncovered certain recognition confusions not easily explained in terms of those structures. This paper presents some solutions to those problems, by hypothesizing a more fragmented, multi-level set of memory structures (MOPs), which are more flexible than scripts. These structures are also expected to account for other phenomena, particularly that of "being reminded" of some previous situation by a current situation.

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Reminding and Memory Organization: An Introduction to MOPs

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A key question for researchers in Cognitive Science is the problem of how human memory is organized. The solution to this problem is fundamental to Cognitive Scientists regardless of whether their basic orientation is towards Artificial Intelligence or Cognitive Psychology. The theories that we test by means of psychological experiments ought to have some ramifications on how we build computer models of the processes tested by those experiments, and the computer models that we build ought to supply testable hypotheses for psychologists. This paper discusses some issues in memory organization that are fundamental to an understanding system, and thus to Cognitive Science.

The continual evolution of our programs that attempt to understand natural language has recently begun to cause an interchange to occur between our group at Yale and various cognitive psychologists. In particular, our work on scripts, as

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embodied in the SAM (Schank et al., 1975, Cullingford, 1978) and FRUMP (DeJong, 1979) programs has caused various researchers outside of our group to attempt to test such notions experimentally (Bower, Black, and Turner, 1979; Owens, Bower, and Black, 1979; Graesser, Gordon, and Sawyer, 1979; Smith, Adams, and Schorr, 1978). Some of those experiments have begun to have an effect upon our theories and upon our subsequent programs. Much of this paper, therefore, attempts to outline the problems we are trying to solve. The solutions we are proposing are at least partially a result of this interplay of psychological and computational concerns.

Some of the ideas related to our notion of scripts (Schank and Abelson, 1977) were tested by Bower, Black, and Turner (1979). In addition to showing that script-like considerations are relevant in story understanding, one of the most valuable things to come out of that work was the problem it presented for us. Recognition confusions were found by Bower et al. to occur between stories about visits to the dentist and visits to the doctor. Intuitively, this result is not surprising, since most people have experienced such confusions. But what accounts for it? Should we posit a "visit to a health care professional" script to explain it? Clearly, such a script would be beyond our initial conception of what a script was.

The right question to ask at this point is what phenomena scripts are supposed to explain. Previously we had used scripts, plans, etc., as data structures which could be used in making the

inferences necessary to create connected causal chains that served as the basis for representing stories. But we always believed that scripts were more than just useful data structures. Scripts ought to tell us something about memory as well as processing. In Schank and Abelson (1977) we claimed that final memory representations for stories involving scripts would use scripts as the basis for those representations. For example, our memory of a story about going to a restaurant would consist only of a pointer to the script $RESTAURANT. One would recall an "INGEST" action by recognizing that INGESTING was a normal occurrence in $RESTAURANT. This is easily accomplished by saving the particular values of script variables set when reading a story. In this view, we remember only the salient new information and do not pay attention to the old stereotyped information. $RESTAURANT (lobster, John, Lundy's) should be enough to regenerate a rather dull story.

Our problem in this paper, however, is not the final form of the story, but the initial form and level of the information that we use in understanding the story in the first place. If we used $DENTIST to interpret a relevant story, why should the remembrance of the story get confused with one that used $DOCTOR? If we used $HEALTH-CARE-VISIT, are we saying that there is no possibility of confusing a dentist story with a story about a visit to an accountant's office? If we use $OFFICE-VISIT, what kind of entity is that? Do we really have information stored at that level to help us understand stories? If we do, then understanding such a story becomes much more complex than we had

initially imagined. We cannot get away with simply applying scripts. Rather we will have to consult many levels of information at once.

Why would we store new inputs about dentists in terms similar to a visit to an accountant? It seems unreasonable on the surface unless we simply do not have a dentist script available at all. Is it possible that there are no dentist scripts?

Another question for AI researchers is, why haven't we run headlong into this problem before? The answer is, I think, that while psychologists worry about recognition confusions in due course, as a part of their natural interest in memory, (see Crowder, 1976; Kintsch, 1977). AI has not really concerned itself with memory at all. We have not been constructing our programs with memory in mind, so the issue hasn't come up. However, it seems obvious that what we posit as a processing structure is likely to be a memory structure as well, and this has profound implications for an understanding theory.

2. Levels of Memory

The problem that we must deal with then is the question of what kinds of knowledge are available to an understander. In answering this question we must realize that every theory of processing must also be a theory of memory. To put this another way, if psychologists were to prove that recognition confusions occur between two entities in memory, it would have to be taken as a disproof of a theory (or a program) that claimed those two entities should be processed by entirely different means.

Thus, in order to address the question of what kinds of processing structures people have, we should investigate the kinds of things people are capable of remembering and confusing. It seems obvious that people have processed whatever they have in memory at some time prior to its presence there, so this seems a natural place to begin.

One type of thing that people can remember in some detail are particular experiences that they have had. So, we will postulate a level of memory that contains specific remembrances of particular situations. We call this EVENT MEMORY. Examples of what might be found in EVENT MFMORY include all the details of "going to Dr. Smith's dental office last Tuesday and getting your tooth pulled" and "forgetting your dental appointment and having them call you up and yell at you and charge you for it last month." EVENTS are remembered as they happen, but not for

long. After a while, the less salient aspects of an EVENT fade away. Such details would includes, for instance, where you got the phone call, or why you forgot your appointment. (Here salience can be defined using a number of different metrics including properties of unusualness, connectedness in a causal chain, or general importance to goal pursuit. (See Schank, 1978.)) What is left are GENERALIZED EVENTS plus the unusual or interesting parts of the original event from EVENT MEMORY.

A GENERALIZED EVENT is a collocation of EVENTS whose common features have been abstracted. This is where general information about situations that have been experienced numerous times is held. Particular experiences are initially a part of EVENT MEMORY. However, when such particular experiences refer to a common generalized event, <u>that generalized event is brought in to help in the processing of the new input.</u> Once the connection between an event and the generalized event that it references is established, the event itself is liable to gradually fade away leaving only the pointer to the generalized event and the salient features of the event not dominated by the generalized event.

Memory for generalized events relies in a similar way upon what we shall call SITUATIONAL MEMORY. <u>Situational Memory contains information about specific situations in general.</u> For example, information about "going to a health professional's office" or "getting a health problem taken care of" are instances of the kind of knowledge that resides in SITUATIONAL MEMORY.

In the understanding process, information found in Situational Memory is used to provide the overall context for a situation. When we go to a dentist's office and something happens there, e.g., you are overcharged, or you meet a pretty girl, the specifics of the dental part of the experience are unimportant in the same way that what telephone you were using is unimportant in the example given for Event Memory above. Situational Memory serves as a repository of relevant contextual knowledge as well as the final storage place for relevant parts of new events in memory. Thus it contains relevant contexts and the rules and standard experiences associated with a given situation in general. For example, the fact that health-care assistants wear white uniforms is information from Situational Memory. This comes from what we previously called the "visit to health care professional" script, but it should be clear that it is by no means a script. The form that it takes will be discussed later.

The next level of memory experience is INTENTIONAL MEMORY. Information encoded in Intentional Memory includes such things as "going to any organization's office" or "getting any problem taken care of by a societal organization". What resides here are the rules for getting people to do things for you and other plan-like information. But the distribution of memories among various levels could lead, once again, to memory lapses or confusions. Thus, specific events would lose the particulars that were best encoded at other levels on their way up to the Intentional level, leaving things like: "once I had a problem

that I was getting some guy in an office to handle, I don't remember where or why I was there, when I got so mad..."

People often cannot recall the full details of a situation they are trying to remember (Bartlett, 1932). Often they can recall just the intentions and not the specifics or alternatively just the specifics and not the intentions. What such experiences suggest is that events can be decomposed into the pieces having to do with their intentional basis and these intentions can then serve as the organizational focus where the relevant parts of such experiences can be found (Black and Bower, 1979).

3.The Place of Scripts

What, then, has happened to scripts? In particular, what is the dentist script and where can it be found in memory? The answer is that there is no dentist script in memory at all, at least not in the form of a list of events of the kind we have previously postulated. A more reasonable organization of memory would allow for the following kinds of information:

EM - Particular dental visits are stored in event memory (EM). These memories decay over time and thus are not likely to last in EM for a very long time. Rather, what will remain are particularly unusual, important, painful, or otherwise notable visits or parts of visits. These are stored at the EM level in terms of the particular events that composed them.

GEM - At the GEM level, we find the information we have learned about dental visits in general that is applicable only to dental visits. Thus, "sitting in the waiting room" is not stored at the GEM level. The reason it is not stored at that level is clear; the lack of economy of storage would be fearsome. We know a great deal about office waiting rooms that has little to do with whether or not they were part of a dentist's office.

What is particular to a dentist's office is, perhaps, the X-ray machine, or the dental chair, or the kind of light that is present and so on. These items are not scriptal in nature. Rather, they are just pieces of information about dental offices that are stored as part of what we know about them. For example, one might expect to find a giant toothbrush in a dentist's office. Such information is stored at the GEM level. However, it is also available from the EM level in terms of those particular experiences that can be remembered at that level of detail. (Such memories fade fast, however.) That is, to answer questions about dental offices, there is nothing to prevent us from consulting our knowledge of dental offices in general (GEM) or of particular prior experiences (EM) to the extent that they still exist.

So where is the dentist script? So far it hasn't surfaced. In fact, it will not appear directly in memory at all. The next two levels complete the framework for allowing <u>dynamic creation of the pieces of the dental script that are applicable in a given situation for use on demand</u>. The dentist script itself does not actually exist in memory in one precompiled chunk. Rather, it, or more likely its needed subparts, can be constructed to be used as needed.

According to this view of the information in memory, then, scripts do not exist as permanent memory structures. Script-like structures are constructed from higher level general structures <u>as needed</u> by consulting the rules about the particular situation

from the three other levels.

The words "as needed" are very important. Why bring an entire script in while processing if only a small piece of it will be used? If scripts are being constructed rather than being pulled in whole from memory, only the parts that there is reason to believe will be used (based upon the input) would be brought in. The economy of such a scheme is very important. Its implementation would require the kind of modularity in memory structures advocated, for different reasons, by Charniak (1978).

To summarize so far: we are saying that scripts are not data structures that are available in one piece in some part of memory. Rather, script application is a reconstructive process. We build pieces of scripts as we need them from our store of knowledge to help us interpret what we receive. Thus, the next key question is: what is the organization of the knowledge store? This is another way of asking the question: What kinds of knowledge do we have and how is that knowledge represented and used in the understanding process?

There are two other relevant questions to ask of memory, which are related. First, how does any given experience get stored so that it will provide a capability for understanding new experiences in terms of it? And, second, why do recognition confusions occur at all?

One answer to the second question depends on the notion of memory as a reconstructive process, one that abstracts out general information from a class of particulars to build concepts made up of episodically generated facts. Since each new piece of information is stored in terms of the higher level structure that was needed to interpret it, two kinds of confusions occur. Connections between items in the same episode that are interpreted by different high level structures will tend to break down. A waiting room scene will tend to disconnect from the dentist script of which it was a part because it was interpreted by a different high level structure than other parts of the story.

The second kind of confusion will occur within a script. When a high level structure is deemed relevant, all inputs are interpreted in terms of the norm. This causes small details not normally part of a script to get lost and normalized. Normalization does not occur for very interesting or weird deviations from a script. The reason for this has to do with the answer to the first question above.

4. Reminding

We have been dealing in all our previous work with the issue of how information is represented in memory and how that information is used in the processing, or understanding, of inputs. Sometimes during the processing of new inputs an interesting phenomenon occurs, namely, you are reminded of a previous experience that is somehow similar to the new input currently being processed. Such reminding experiences are not random. Rather they are dependent upon the very nature of the understanding and memory processes we have outlined.

The answer to the question of why one experience reminds you of another is of primary importance to any theory of human understanding and memory. If people are reminded of things during the natural course of a conversation, or while reading, or when seeing something, then this tells us something of great importance about the understanding process. It tells us that a particular memory piece, that is, a specific memory, has been excited or "seen" during the natural course of processing the new input. We can then ask two important questions:

1- Why did processing naturally pass through this piece of memory? That is, what is there about the processing of new information that requires a particular related piece of information to be noticed?

2- How did such a mechanism as reminding develop? That is, what is the purpose of reminding?

We can begin to attempt to answer these questions by considering the kinds of reminding experiences that people have. One immediate point that comes to mind is that experts in particular fields might be expected to have reminding experiences directly tied in with their expertise. Thus for certain people, we might expect reminding experiences corresponding to:

1 - known chess patterns

2 - known political patterns

3 - previously encountered similar situations

4 - patterns of erratic behavior

5 - patterns in theory development

6 - types of football plays

7 - kinds of music or paintings

What such "high level" reminding experiences imply is that in order to understand something you must process it to the highest useful knowledge structure. (Later, we will discuss some exceptions to this rule that occur at memory levels that are even higher than those we have discussed so far.) Since this structure is a memory piece responsible for both understanding and storage of other like events, the arrival at such a structure could be expected to cause the information stored there to be noticed. To do this, we need complicated tests, such as a discrimination tree provides, that serve to identify an input as belonging to a particular knowledge structure.

For example, there is a restaurant in Boston where you pay first, then eat, called Legal Seafood. Going to another such restaurant and saying "this restaurant reminds me of Legal Seafood" would of course be quite natural. The way this theory accounts for this is that the restaurant script is merely a first approximation as to where search should begin for the most appropriate memory structure to be used in processing the new input. Thus, initial access of the restaurant script merely serves to begin our search for the memory structure that will be used to understand this new experience. Accessing the restaurant script just means finding a relevant entry point to memory. We have, rather than a discrete set of such high level structures, a potentially infinite set. There is not one restaurant script but thousands. The various refinements on restaurants all serve as nodes in memory that help to reconstruct a needed high level structure. By saying to ourselves, "gee, you pay first here", we have caused our minds to traverse a path within the information organized by restaurants in order to complete our search for the highest level structure (i.e., the structure that explains the most information). At the end of that path is Legal Seafood, so reminding occurs.

More important than reminding, however, is that all the events from that previous experience are now available as predictions to help interpret the new input. Such predictions function no differently if the new input calls up a once-seen prior relevant experience or a multitude of experiences expressed in terms of high level generalizations such as "the restaurant

script". (Of course, many of these predictions turn out to be quite useless or even wrong. Interpreting past experiences according to the relevance of the pieces of that experience for predictions of future events is thus an important part of understanding new events.)

The logical consequence of all this is that there are a potentially infinite set of such structures and that most people's sets would be extremely large and idiosyncratic. For example, an expert at chess would be able to recognize "famous games" or positions that he has seen before. Such recognition depends on the use of a high level structure in the first place of the kind we have been discussing that would have been part of the understanding process. That is, during understanding, we are constantly seeking the highest level of analysis we can get. This works for understanding chess as well as anything else.

5. Understanding

According to the above view of memory, we can now re-evaluate what it means to understand. When we enter Burger King, after having been to MacDonald's but never having been to Burger King, we are confronted with a new situation which we must attempt to "understand". We can say that a person has understood such an experience (i.e., he understands Burger King in the sense of being able to operate in it) when he says, "I see, Burger King is just like MacDonald's."

To put this another way, we might expect that at some point during his Burger King trip he might be "reminded" of MacDonald's. The point I want to make is that understanding means being reminded of the prior experienced phenomenon that is most like the input, and being able to use that prior phenomenon as a source of expectations relevant to current processing. That is, when we are reminded of some event or experience in the course of undergoing a different experience, this reminding behavior is not random. We are reminded of this experience because the structures we are using to process this new experience are the same structures we are using to organize memory. Thus, we cannot help but pass through the old memories while processing a new input. There are an extremely large number of such high level memory structures. Finding the right one of these, (that is, the one that is most applicable to the experience at hand) is what we mean by understanding.

Is it any wonder that we are reminded of similar events? Since memory and processing structures are the same, sitting right at a very spot will be the experience most like the current one. Voila-- reminding.

In this view then, understanding is finding the closest higher level structure available to explain an input and creating a new memory node for that input that is in terms of the old node's closely related higher level structure. Understanding is a process that has its basis in memory then, particularly memory for closely related experiences accessible through reminding and expressible through analogy.

6. Memory Discriminations

Now the question is, how do we go about finding what is stored in memory?

Suppose you had an experience where you wanted to donate blood, stood on a long line in a school gym to do so and were rejected. Then imagine an experience a year later of standing on a long line at an eye bank to sign up to donate an eye and also being rejected. It seems obvious that the second experience would remind you of the first. How can we explain this? We could hypothesize a "rejection after waiting to donate body part" category, but how would this category be found? To further focus this question, we can ask whether we would normally expect to find a list of all rejection experiences or of all mass health care donation visits? Somehow neither of these seem quite right. When asked to remember rejections people tend to first imagine situations in which such a rejection might have occurred.

On the other hand someone who regularly gives blood might very reasonably be expected to have compiled these experiences in a script with discriminations as we have described. So what organization of memory is right?

The answer I think is that all of these are right. Memory is highly idiosyncratic. One person's organization is not another's. How people categorize experiences initially is how they remember them later. If Burger King is seen as an instance of MacDonald's it will be stored in terms of whatever features

the understander noticed as relevant at that time. However, it is possible for a person to make multiple categorizations. Thus, a person can see Burger King as "something tasteless that kids love", a "place where red and yellow uniforms are worn" and a "place where you can have it your way". Each of these could then be used as a path by which Burger King can be accessed. A fight with one's child in a Burger King might be stored solely as an instance of a fight with a child, or as a fight in a restaurant, or as a fight in a Burger King. If the latter categorization were used, fights with a child in MacDonald's might not be noticed. Thus, an intelligent understander stores his experiences as high up and as generally as possible so as to be able to learn from them, i.e., so as to make them available for use as often as possible or in as many situations as possible.

It is important then to have Burger King (and every other item in memory) accessible by a large number of very complicated discriminations:

Red & Yellow Uniforms in Fast food — Have it your way — Tasteless and kids love it

Burger King

Drive thru fast food — Talking box to order in — Tacos available with hamburgers

Jack in the Box

One problem in understanding, then, is to make initial categorizations of new input that correspond to old categorizations in terms of which items have been stored in memory. The total number of discriminations that point to a concept indicates how well that concept has been initially categorized and thus understood. Undergoing an experience and not making lots of discriminations that lead to it is an instance of not really paying attention or understanding. An intelligent person paying lots of attention to what's going on will create a large number of discriminations (sometimes ones that are quite unique) for what he has seen.

The first problem is making the initial categorizations. Then we have to be able to find them again. For example, a categorization in terms of the results of an experience seems likely. Thus, if all fast foods places are seen as "tasteless and kids love it", then we can expect an understander to classify them all together. Then, at the bottom of the same node, unless discriminations are made, distinctions will get lost:

```
                                    enter via fast food
                 tasteless and kids love it
       Burger King
       Jack in the Box
       MacDonald's
```

The solution to problem one above, then, is not having Burger King or any other memory item accessible by only one possible path in memory. That is, different aspects of Burger King are stored in different memory classifications of various

aspects of Burger King. Thus it is possible to have inconsistent beliefs about Burger King such that it would be very difficult to retrieve all that we know about Burger King.

If small distinctions such as "tasteless food" or "having it your way" are relegated to being all the way at the end of a complicated discrimination tree, then there will be little possibility for understanding by analogy or reminding experiences that cross gross initial characterizations. We might expect that we would be reminded of Burger King by a fried chicken fast food place (say, Texas Fried Chicken) that allowed a choice of herbs and spices. But how are we to be reminded of Burger King by Texas Fried Chicken if the only way to find the Burger King experience is by first entering a tree whose top node is "hamburger place"?

This problem can be solved by having all the small particular characterizations at the very top of the available discrimination trees. Doing this implies having a very large number of initial categorizations at the bottom of which can be found Burger King. Thus if Burger King is available in many different places and <u>there are many different ways to get to aspects of what is essentially the same node</u>, then understanding by analogy can take place:

red & yellow uniforms	tasteless, etc.	have it your way	fast food hamburgers
Burger King Hardees	Burger King Jack in Box MacDonald's	Burger King Texas Fried Chicken	Burger King MacDonald's

Burger King

But doing it this way indicates that the same unique token for Burger King is what is to be found at the bottom of each tree. In the normal form of the type-token distinction, that is what happens. But this is not necessarily the case here. There is no reason to believe that all memories of Burger King are available simply by reference to any one of them. It is not necessarily the case that these links are traversable both ways.

What is even more likely is that all memories of Burger King experiences are not stored in the same place at all. The only time that we would expect a Burger King experience to be stored with another one is when those experiences were not distinguishable in any significant way. Interesting aspects of Burger King (or any other experience) are stored in a multitude of places depending on the aspects of the experience deemed significant at the time of initial processing. Again, we see that the key question is exactly what kinds of initial categorizations are likely to be made at processing time. In attempting to answer this question we must keep in mind that a good answer would have any one of these initial categorizations dependent on some processing issue. That is, there should have been a reason at the time of processing, because of processing

considerations, to make the initial categorization in that way.

One processing argument might be that the "have it your way" path to Burger King must have gotten there by once noticing that in a Burger King, there was a choice of ingredients within the normal functioning of the fast food script. Now, this could be represented in a number of ways within memory. First, it could be part of the script in schematic form, such that whenever a similar script-break occurs, normal processing would find the Burger King event stored at that breakpoint. Another way of dealing with it might be to pop up a level, storing it as something like "breaks from the normal in fast food restaurants", or "script failure problems", or "choices while eating". Probably all of these are used as discriminations in a myriad number of trees all of which point at the bottom to Burger King.

Two consequences of this proposal appear immediately. First, the initial processing that takes place will now have the burden of having to categorize each input in terms that begin the discrimination process. Second, we can see that the trees that result from these categorizations will be very sparse with next to no depth. For example, Burger King can be dealt with as "establishment where more choices than usual occur". Such a categorization gives us a "tree" of one discrimination, namely that one, at the end of which is Burger King.

Now suppose that we encounter another establishment where a choice is possible. We will not necessarily characterize it that way, i.e., that might not be a salient feature to an understander

at processing time. If that were the case no "reminding" of Burger King would take place. But, if that were noticed, then such a "reminding" would occur. The consequence and use of the reminding would be to bring to bear other possible expectations from scripts associated with Burger King or particular experiences associated with Burger King. These expectations are what makes processing go and enables understanding.

An example here will serve to illustrate the categorization issue. Someone told me about an experience of waiting on a long line at the post office and noticing that the person ahead of her had been waiting all that time to by one stamp. This reminded me of people who buy a dollar or two of gas in a gas station. What could be the connection there? Quite obviously, I had characterized such motorists as "people who prefer to do annoying tasks over and over when they could have done them less often if they had purchased larger quantities in the first place". Now such a node may seem extremely bizarre. Nonetheless, I can see no other way to explain one of these experiences reminding me of the other.

Viewing conversations in general, we see experiences such as this again and again. One person responds to another's story with one of their own that is related only by a few essential features. Such conversations are considered coherent, but what is more surprising is that these jumps from topic to topic occur naturally during the understanding process as a normal part of it.

However, the issues of categorization involved here are not as frightening as I made them appear in this example. Recall that I have argued that processing considerations should be the impetus behind initial memory categorizations. If we ask what kind of processing issues might exist in common between the post office experience and the gas station experience we find that in the goal-based analysis of the kind we have proposed in Schank and Abelson (1977) and in Wilensky (1978b), there is a very obvious similarity. Both stories relate to goal subsumption failures (this term is due to Wilensky, 1978a). In processing the post office story it is necessary, as it is in most stories, to attempt to understand why the actor did what he did. Questions about the motivations of an actor are made and answered until a level of goal-based or theme-based explanation is reached. Why he bought a stamp is easy, as is why he stood in line. But good goal-based processing should note that this story is without point if only those two goals are tracked (Schank and Wilensky, 1978). The point of the story is that the actor's behavior was somehow unusual. The unusualness was his failure to think about the future. In particular, he could have saved himself future effort by buying more stamps either before now or at this time. But he failed to subsume this goal. That is the point of the story and thus the highest goal-based level to which the story is processed.

One key issue in the reminding and memory storage problem, then, is the question of what higher level memory structures are used in processing a new input. We have already worked with some

of these structures in Schank and Abelson (1977), Wilensky (1978), and Carbonell (1979). As with scripts, psychologists have found goal structures useful in predicting human memory for stories (Black and Bower, in press). We have high level structures in memory corresponding to Goal-Blockage, Goal-Failure, Goal-Replacement, Goal-Competition and so on, not to mention the various structures associated with satisfying a goal. Each time a high level knowledge structure is accessed during normal processing, the piece of the story being processed relevant to that structure is stored at that processing-related node.

In summary, memory can be conceived of as being organized around processing considerations. Particular experiences in memory are likely to be found at the structures that were used to process them, with fine discriminations being used to create an essentially infinite set of such structures. The use of such structures is for prediction and explanation of future events based upon prior experience. The initial discriminations or categorizations in memory include those related to the tracking of goals in general. Memory is thus organized by both goal issues and processing considerations. Reminding may be at times simply an artifact, but it is at other times an important part of the basic understanding mechanism.

To conclude this section, I will attempt to illustrate the processing-based organization of memory by returning to the Burger King example and then to scripts in general. We have been

toying with a "have it your way discrimination" which has seemed a bit ad hoc. What is the proper organization of discriminations that would allow for a fried chicken place that offered choices of herbs and spices to remind one of Burger King? If we view a fast food script as being organized temporally, then what we see is a "choice point" in the ordering scene that is more than the usual for that script. That is, one is being asked not only to choose what one wants to eat but also one has an opportunity to say something about the preparation of what one has ordered. This unusual feature is treated as special within the script to the extent that the memory of the Burger King choice point is stored there as a potential embellishment to the script. We shall see how this works in detail in the next section.

During the course of some early presentations of the ideas on reminding expressed here, one question that I was asked was why when you enter a restaurant you are not reminded of all restaurants or of that particular restaurant? I believe the answer is that you most certainly are. When you enter Naples (a Yale hangout) you are reminded of Naples. You then use that reminding as the source of predictions about what will happen next. That is, you use the most particular script available to help you process what you are experiencing. When Naples reminds you of Naples you do not experience the same sensation of reminding for an obvious reason. The more appropriate a reminding experience is, the less it seems like a reminding. But reminding is simply the bringing to mind of highly relevant memories to help in the processing of new inputs. To say or to

feel upon entering a new restaurant that "this place reminds me of a restaurant" is rather absurd, but remind you it does. If this were not the case how would you know that it was a restaurant? Thus, reminding is not simply an interesting but somewhat peripheral phenomenon. Reminding, in a very serious sense, is the most significant memory phenomenon that there is to explain.

7. What Memory Looks Like Inside

In the scheme we have outlined so far, scripts are formed for actual use by building them up from scenes that may be stored with higher level structures. However, in building up a script this way we are also allowing for the possibility of input events being remembered in terms of the highest level structure that was used to process them. Doing this causes the script that was temporarily built up for processing purposes to be broken down again, thus resulting in memory confusions and a certain lack of connectivity between the scenes of a story as it is stored in memory.

Thus, we are beginning to see that the pieces that make up a script, i.e., the scenes, are the basic memory units. But, people make predictions about what will happen next from all their prior experiences, not just from scene-based memories. A person who has experienced something only once will expect his second time around to conform to the initial experience and will be "surprised" in some sense, every time the second experience does not conform to the first. Thus, an important issue in memory organization and expectation is the script acquisition problem.

Scripts get put together in the first place by first storing one experience, then mushing another on top of it, strengthening those areas of agreement and noting discrepancies. But obviously there are times when "new" experiences for which there is one or

no prior experiences can occur in the middle of an old well-understood experience. That is, new experiences need not be only in terms of contexts that have never happened before. They can just as well occur within contexts that have happened many times before, such as restaurants. Thus, when you go to Legal Seafood you modify your restaurant script so as to indicate that the PAYING scene has been placed immediately after the ORDERING scene in memory. What I want to propose is that what is happening here is not the creation of a new "track" in a script (see Schank and Abelson, 1977, and Cullingford, 1978, for discussions about tracks). In fact, I now see very little evidence for tracks at all. Rather, the entire memory experience is being stored under this interruption or abnormality following the ORDERING scene.

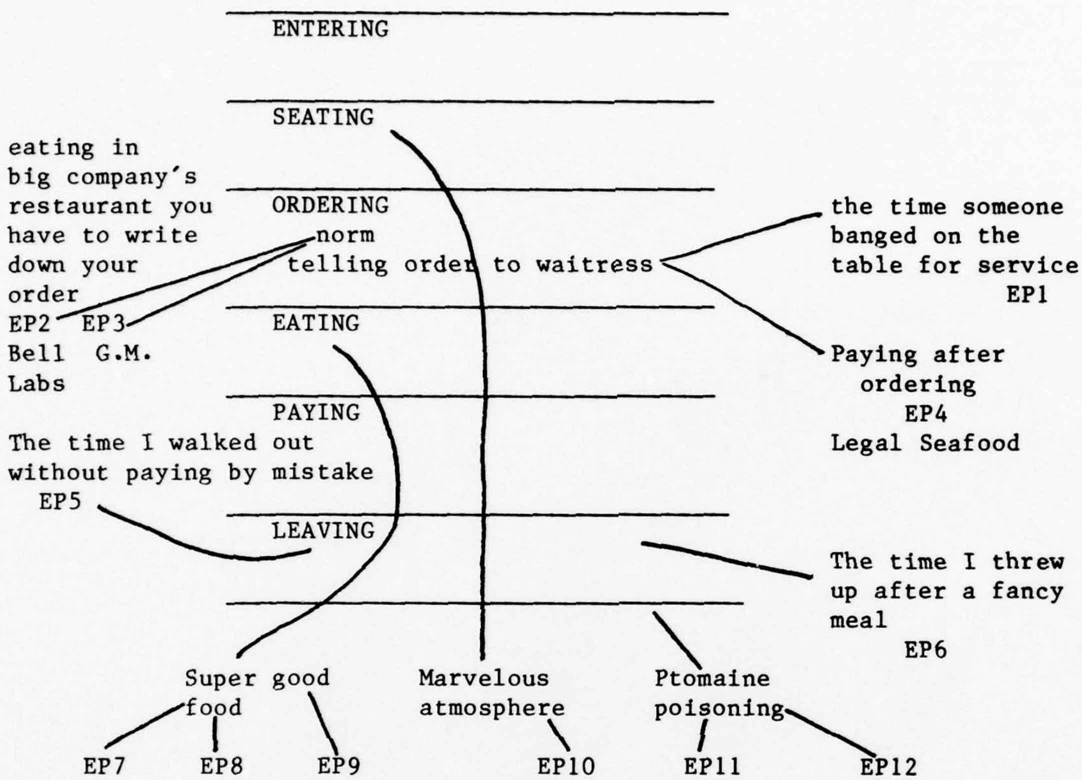
Two kinds of reminding exeriences are accounted for by this. First, any other script readjustment occurring after ORDERING might remind one of Legal Seafood. Second, a new placement of the PAYING scene in the restaurant script might be expected to remind one of Legal Seafood.

Now what does this reminding buy you? The reminding actually causes the whole rest of the reminded experience to be brought into memory at this point just as would happen with any new experience not accounted for by a well-trodden script. This experience is now used, just as a script would be, to predict what will happen next and to help complete a causal chain by making inferences.

Thus, deep down inside the guts of a script, we find all the pointers to every memory experience we have had that has been organized in terms of that script and that has not been obliterated by multiple identical experiences. Script application is embellished by going down paths which the script itself organizes, that contain all prior deviant (i.e., not completely standard) experiences. These experiences are functionally identical to scripts and thus are an integral parts of the application process. This can occur within any script-piece at all.

As an example of all this, consider the following picture of a possible set of memory experiences tied to, or organized by, the restaurant script.

$RESTAURANT



From this diagram we can see that the ultimate purpose of scripts is as organizers of information in memory. The restaurant script that we have used in the past is no more than the standard default path, or basic organizing principle, that serves as the backbone for all remembered restaurant experiences that have been stored as restaurant experiences. Thus, we are saying that every deviation from the standard script is stored as a modification of the particular scene in which the deviation occured. These modifications are themselves small chunks, or scenes, that are accessible from a variety of paths, one of which is the deviation in the restaurant memory structure.

So, one experience in Legal Seafood causes a deviation in the ordering scene to be noticed. (Such deviations were previously referred to as being on the "weird list" in Schank and Abelson, 1977.) This deviation serves as both the beginning of a reminding experience and the start of the script application process. But, storage and processing must be taken care of by the same mechanism in order to get natural reminding to take place. In addition, the scheme that I am proposing allows for the use of all prior experiences in the interpretation of new experiences rather than a reliance on only standard normalized experiences (i.e., what we have previously called scripts). This scheme works as follows: Information about a restaurant is processed in the normal way by the use of the restaurant script. The major difference is that each scene is applied one by one as needed. Thus, the entire script is not brought in at once. As long as the story is "normal" no deviation from the usual default script is noticed, and no reminding occurs. But, hidden underneath the restaurant script's bare backbone are all the memories that have ever been classified in terms of restaurants. As soon as an abnormal event (i.e., unusual to the extent that its occurrence is not predicted by, or actually contradicted by, the normal flow of the script) occurs, the scene that it occurred in is used as an entry point into a memory chunk that is hung off that scene. In the diagram above, we have four deviations in the ordering scene. In EP1, there is the experience in which someone at my table banged the silverware on his plate repeatedly to get service. In EP2, we have my remembrance of having to write down

my order at Bell Labs. In EP3, we have a similar experience at G.M. In EP4, we have the experience in Legal Seafood of being asked to pay immediately after ordering.

Now a key point here is this: What is hanging off the discrimination tree that encodes these experiences as deviations from normal ordering is not a "track" or "subscene" that gives alternative paths through the script. Rather, the entire episodes associated with these experiences are there. The fact that they are there is evidenced by the fact that reminding takes place in such situations. At Bell Labs I was reminded of G.M. When one is reminded in this fashion one is not just reminded of the ordering scene at G.M. Rather, the entire experience comes to mind, although that experience is accessed through (i.e., entered by way of) the ordering scene. Thus the restaurant script serves as a point of departure from which the rest of the GM experience can be recalled or reconstructed. Thus, after the GM ordering episode is entered, all the rest of the GM experience is available as well. This availability has two very important possible uses.

First, relevant predictions of the kind we have previously said were available from scripts, actually come from whatever prior experiences are available. Thus, the rest of the happenings at G.M. can then be used to interpret what happens at Bell Labs. Such predictions can even encompass events that are in no way restaurant-related. The importance of this capability cannot be overemphasized. People interpret new experiences in

terms of old ones. The only way to get the relevant older experience to be available is to have been reminded of it in the normal course of processing the new experience. Noticing that Bell Labs is like G.M. in the ordering scene can then allow for remembrances of the G.M. experience to guide future behavior at Bell Labs.

Often, of course, there is no need at all for the remembered experience. Once one is reminded of G.M., one can then ignore this reminding. That is, one can decide that no predictions from one experience are relevant in the new experience and one can return to normal processing by going back to the normal backbone of the script. Alternatively, it is possible to never return at all to the normal script since its predictions are so general, and to use instead the predictions of the reminded events to guide processing.

Whatever choice is made, a new episode has been experienced and part of a processor's decisions at this point include the problem of storing the new episode. The issue here, first, is where pointers are left to the entire Bell Labs experience; second, at what points the Bell Labs experience is broken up into pieces of episodes that lose there relatedness to each other; and third, what the overall effect on memory and future processing is.

The answer to the first question is that since the deviation in ordering has been seen before, a pointer to the G.M. episode that existed previously at the "write down order" deviation is

now joined by a pointer to the scene that is the reminded part of the Bell Labs episode.

However, to answer the second question requires having analyzed the new Bell Labs episodes in terms of all the relevant higher level knowledge structures that were used to process it in the first place. We can expect that "lecturing", "talking with colleagues", "consulting", and so on, might all have been used in addition to "restaurant". As we said earlier, there is no reason to believe that all of these are connected to each other. So our new pointer at the ordering deviation points to that part of the experience that contains "restaurant" and other pieces of the entire experience that may be causally connected to the restaurant part of the entire Bell Labs episode.

The answer to the third question above is the second important issue we previously referred to. Memory can be affected by such a deviant experience in two possible ways. First, if the deviant experience has no counterpart, e.g., if there had been no prior G.M. experience or if the Bell Labs experience differed at the ordering scene in some significant way from the G.M. experience, then a new deviant path off of the ordering scene in the first instance or off of the G.M. deviation in the second would have to be created. This deviation would consist of the entire relevant experience at Bell Labs with respect to ordering and would now serve as a new source of relevant predictions down deep in the restaurant script. Thus we are saying that all prior experiences, if classified initially as

being interestingly deviant, serve as embellishments to the script of which they are a part, and thus as sources of predictions.

If the new experience does have a counterpart, that is if similar deviations have been met before, at some point these experiences are collected together to form a generalized event whose predictions are disembodied from actual episodes like the higher level restaurant script itself. Thus, at some point the understander notices that not only do G.M. and Bell Labs have you write down your order, but so do various faculty clubs and other company lunchrooms. When enough of these are encountered, a new subscene is created that will not cause one to be reminded of the particular experiences that caused him to create this subscene. As this subscene gets created all pointers to the relevant episodes that helped to create that subscene are erased, although other pointers not a part of this subscene but pointing to the same episode would still exist. Thus, an argument at lunch at the Harvard faculty club might still be remembered, but it would not be possible to get at it through the deviation in the ordering scene of writing down your order any more than it would be possible to get at it by the sitting down scene or any other normalized scene.

Thus, memory collects similar experiences to make predictions from that are of general utility (above some threshold of a number of prior experiences.) Below that threshold, remindings of prior experiences serve as the source of

relevant experiences. Thus, uniqueness of experience, or more accurately, unique classifications of experience, serve as a rich source of understandings about new experiences. Repeated experiences would then tend to dull a person's ability to respond to the world around him by lulling him to sleep during processing, as it were.

One important factor in the automatic creation of script predictions that we have been arguing for is the understanding of what events belong to what set of predictions. For example, the one time I actually ate in Legal Seafood, I had a long discussion about politics with a friend that became a focal point for part of the evening. The topic of that discussion, or arguments with that particular person, might remind me of that experience as well as the reminding that we have been discussing.

In the process of script embellishment via deviant paths we are accessing an entire episode, much of which may have next to nothing to do with the story currently being processed. It is important to be able to separate the relevant from the irrelevant. It would not be very useful to predict an argument the next time I encountered a restaurant where you pay right after ordering. On the other hand, it <u>is</u> hard to not be reminded of irrelevant parts of the experience as well. This is one aspect of intelligence that comes into play here. The discrimination of those experiences that are relevant for prediction, and those that are irrelevant, is one of the most formidable tasks facing an understander. <u>Such discriminations</u>

must be done at processing time since one cannot know beforehand where relevant similarities might lie for future inputs. Thus, a very important part of understanding is the analysis of what is happening to you now with respect to the issue of how a relevant newly encountered event might be for predictive purposes. The collocation of arguments and "paying right after ordering" is not a useful category for experience-based prediction. Clearly we are not born knowing such things. What form such knowledge takes and how we go about acquiring it, is one of the very big issues for future research.

8. Memory Organization Packets

If the chunks we have been calling scripts are not solely processing devices, the demands on them change. Just as we would not expect that a sensibly organized memory would have the fact that George Washington was the first President stored in fifteen different places, we would not expect that "you eat when you are hungry" or "you order after reading a menu", or "if you don't pay your dentist bill you can be sued" to be stored in fifteen different places either. This does not mean that there is no redundancy at all in memory. Indeed, particular experiences can always be used to rederive generalizations drawn from them if need be.

Once the requirement that you have to find one and only one place to store such <u>general</u> information comes into play, the question of where that information is stored becomes extremely important. To decide that question, notions such as scripts must be tightened up considerably so that information shared by any two scripts becomes a significant generalization made from them, and is stored outside them in memory. To do this requires ascertaining what it might mean for two scripts to share the same information, and finding out when such sharing is "realized" in memory and when it is not.

While we require that general information be stored in only one place in memory, specific episodes are treated differently. Specific episodes can be multiply categorized, that is,

remembered as instances of many different phenomena at once. Thus, experiences can be recalled through many different aspects of them. Often, pointing to an episode by virtue of having used a particular characterization of that episodes, can cause other parts of that episode to be recalled. In those instances the different aspects are being used as pointers to the one place in memory where the entire episode resides.

9. Learning to Abstract

Children, as we have noted in Schank and Abelson (1977) and as Nelson and Gruendel (1978) have shown, are learning scripts from a very early age. What I want to hypothesize is that the basic entity of human understanding is what we have termed the personal script. Personal scripts are our private expectations about how things proceed in our own lives on a day to day or minute to minute basis. In the beginning, a child's world is organized solely in terms of personal scripts, i.e., one's private expectations about getting one's diaper changed or getting fed by mama or going shopping with mama. Such expectations abound for children and children can be quite vocal when these expectation are violated. The child who has gotten a piece of candy during every grocery store visit will complain wildly when he does not get one at the current grocery store. These expectations are not limited to such positively anticipated experiences however. Trifles such as taking a different route to the same place or not being placed in the same seat as last time are very important to children and serve as reminders to us of the significance of personal scripts in children's lives.

As time goes on a very important thing happens. We begin to notice that other human beings share some, but not all, of our expectations in certain situations. As adults we do not abandon personal scripts as important organizational entities. We still expect the doorman to say "good morning" as he opens the door or expect the children to demand to be played with immediately after

dinner or whatever other sequences we are used to. We may no longer cry when these things do not happen, but we expect them nevertheless. These expectations pervade our lives as much as they did when we were children.

The major difference is our discovery that some of the outside world shares our expectations. This discovery continues to have ramifications for the rest of our thinking days because it causes us to begin the process of abstraction and generalization. When a child discovers that his personal restaurant script is also shared by other people, he can resort to a new method of storage of restaurant information. He can rely on a standardized restaurant script with certain personal markings that store his own idiosyncratic points of view. That is, he can begin to organize his experiences in terms that separate out what is particular to his experience and what is shared by his culture. For example, adults know that getting in a car is not part of the restaurant script. However, this may be a very salient feature of a child's personal restaurant script. It is very important for a child to learn that the car experience must be separated out from the restaurant experience so that he can recognize a restaurant without having gone there by car and so that he can understand and talk about other people's restaurant experiences. Thus, the child must learn to reorganize his memory store according to cultural norms.

This reorganization of stored information can continue on indefinitely. Experiences are constantly being organized and reorganized on the basis of similar experiences and cultural norms. The abstraction and generalization process for experientially acquired knowledge is thus a fundamental part of adult understanding. When you go to the dentist for the first time, everything in that experience is stored as one chunk. Repeated experiences with the same dentist, other dentists, and vicarious experiences of others, serve to reorganize the original information in terms of what is peculiar to your dentist, yourself in dental offices, dentists in general, and so on. The important point is that this reorganization process never stops. When similarities between doctors and dentists are seen, a further reorganization can be made in terms of health care professionals. When doctor's and lawyer's similarities are extracted, yet another organization storage point emerges. An important part of understanding, then, is the classification of new experiences in terms of old ones that are deemed most appropriate or most relevant to that new experience. Information in memory is thus collocated in what we call memory organization packets, or MOPs, which serve to organize our experiences that have been gathered from different episodes into sensible units organized around essential similarities.

10. MOPs

The purpose of a MOP is to provide expectations that enable the prediction of future events on the basis of previously encountered structurally similar events. These predictions can be at any level of generality or specificity. Thus, such predictions can come from nearly identical or quite different contexts or domains since a context or domain can be described at many different levels of generality. The creation of a suitable MOP provides a class of predictions organized around the common theme of that MOP. The more MOPs that are relevant to a given input, the more predictions will be available to help in understanding that input and the better the understanding will be. The ability of MOPs to make useful predictions in somewhat novel situations for which there are no specific expectations but for which there are relevant experiences from which generalized information is available, is crucial to our ability to understand.

Seen this way, a MOP is a kind of high level script. The restaurant script is itself a kind of MOP but it is also related to many different and more general MOPs. There is a MOP about social situations, a MOP about requesting service from people whose profession is that service, and a MOP about business contracts, to name three that are relevant to restaurants.

Actually a great many MOP's relate to the restaurant script. The function of most of these MOPs in the actual use of the restaurant script in processing is minimal. A MOP serves as a storage point for general information abstracted from particular experiences for use by other experiences. Thus, restaurants serve as a source of information from which various MOPs were created since the restaurant experience is likely to have been temporally prior to the creation of the relevant MOPs. When we eat in a restaurant we need not think about the job MOP or the professional service MOP that motivates the waitress. Indeed we are likely never to have thought about such things much at all and certainly not in our early childhood experience with restaurants.

But such information can be of use in dealing with problems that might occur in a restaurant (for example, a waitress who refuses to serve you) or in explaining the behavior of other people in similar situations ("she's just like a waitress"). Those situations are understood in terms of MOPs about jobs and waitresses rather than in terms of the restaurant script. Similarly, calling the police when one cannot pay one's restaurant bill is information about contracts and is thus not part of the restaurant script itself.

To see how MOPs function in processing we will consider the information relevant to a visit to a doctor's office. The primary job of a MOP in processing new inputs is the creation of processing structures (i.e., sets of expectations) necessary to

understand what is being received. Thus, MOPs are responsible for constructing script-like entities that can recognize the proper place of a new input by filling in implicit information about what events must have happened but were unstated. At least five MOP's are relevant to the construction of the processing structures necessary for understanding a doctor's office visit. They are: PROFESSIONAL OFFICE VISIT; CONTRACT; FIND SERVICE PROFESSIONAL; USE SERVICE; and FIX PROBLEM.

As we will see, these five MOPs overlap quite a bit. There is nothing wrong with that; indeed it should be expected that any memory theory would propose overlapping structures since they are the source of both memory confusions and the making of useful generalizations across domains.

When a script is available it can be used without really looking at a MOP. However, because storage of information needs to be economical, we would not expect what is best stored at a MOP to be found in a script as well. Thus, the doctor script would not have the doctor suing the patient for non-payment of the bill directly in it. Neither would the bill itself be in the domain of the doctor script. Each of those is best stored as part of a MOP about CONTRACTs that becomes active whenever the doctor script is activated. A doctor visit need not be actively thought about as a contract most of the time. Nonetheless the fact that it is one is highly relevant to processing some episodes in doctor visits. In order to be ready to make use of this information, then, the CONTRACT MOP must help to construct

what we can sloppily call the DOCTOR "script" that might actually be useful in processing.

It is important to mention that $DOCTOR is connected to the CONTRACT MOP by a strand of the MOP, but that $DOCTOR does not contain that strand, i.e., does not contain information abcut payment other than the presence of that MOP strand. Thus, $DOCTOR is smaller than is obvious at first glance, since we have essentially taken the paying scene out of the script. The actual DOCTOR script that exists in memory contains only the doctor-specific parts of the doctor experience.

Thus waiting room information is not part of $DOCTOR. Waiting rooms are part of PROF OFFICE VISITs which is also a MOP. And PROF OFFICE VISITs is different from MAKE CONTRACT which is different from PROF SERVICE. Each of these MOPs help in the construction of what we shall call the doctor super script. This super script is what we have previously called a script. The difference here is that super scripts are not extant memory structures. Rather, they are constructed for use as necessary to help in processing.

Since MOPs serve a great many purposes in memory and processing, it is necessary that they contain many different kinds of information. Further, it is necessary that that information be structured in such a way as to be available for use in different ways to suit the current purpose. To begin our discussion then, we must first delimit the kinds of uses to which a MOP can be put:

1- MOPs help to build super scripts for processing

2- MOPs direct question-answering

3- MOPs enable reminding

4- MOPs help one to draw conclusions and notice patterns

5- MOPs enable recognition of old situations in new guises

To illustrate how these functions involve MOPs we can consider the MOP PROF OFFICE VISIT. The primary function of PROF OFFICE VISIT (henceforth POV) is to provide the correct sequencing of the appropriate scenes that contribute to the construction of super scripts that make references to POV. In order to build the doctor super script, we must recognize that the various MOPs that contribute to the construction of the super script are applicable. How do we do this? Consider the following story:

> I went to the doctor's yesterday. While I was reading a magazine I noticed that a patient who arrived after me was being taken ahead of me. I am going to get even by not paying my bill for six months!

Previously, in our script-based theory we would have said that the first line of this story called in the doctor script. But the doctor script that we meant there was what we are now calling the doctor super script. We are currently maintaining that no such entity should exist in memory as a prestored chunk. The reason for this is that recognition confusions about whether things that occurred in waiting rooms took place in doctors' waiting rooms or lawyers' waiting rooms would not happen if the requirement that every structure used in processing also be an

episodic memory organizer were maintained and the doctor super script existed as a permanent memory structure. That is, it must be possible to disassociate events that occur in waiting rooms from the super script in which they are found in order to account for Bower, Black, and Turner's results about recognition confusions. As another example of this it might be convenient to imagine that Cyrus Vance has a negotiation script that he uses to organize all the events that comprise a trip to a foreign country to negotiate a peace treaty. But a plane trip is still a plane trip and we might expect Vance to confuse a trip that was part of a negotiation with one that took him to a state funeral.

The point is that there are natural collocations of memories. No matter how convenient it might seem to organize things under negotiation trip or doctor visit for processing any given story, a memory that had such high level structures would not behave the way human memories behave. Furthermore, we would not be able to take advantage of similarities across experiences. That is, a system organized in that way would not be able to make significant generalizations and it could never learn. Thus, it is imperative that memory be reconstructive in nature, building up super scripts as necessary.

Therefore, in processing the first sentence of this story, what we must do is call in the relevant MOPs insofar as we can determine them, and begin to construct the doctor super script to help in processing the rest of the story. This is done as follows: The phrase "went to the doctor" refers to $DOCTOR which

is the script part of the doctor super script that handles the actual doctor specific parts of the entire episode. To begin to construct the super script, we search the DOCTOR MOP. To see what the requirements of this search must be, we should first examine the contents of the DOCTOR MOP.

What is likely to be in a DOCTOR MOP? The answer here is simple: everything we know about doctors should be accessible through the DOCTOR MOP. Either the information we seek is stored directly in the DOCTOR MOP, or else the DOCTOR MOP contains a pointer to some other MOP or some specific episode that is relevant to the reconstruction of that information. The key question is what information is to be found where. That is, how is the DOCTOR MOP organized? What I shall propose is that there are several kinds of MOPs. The DOCTOR MOP is what we shall term a simple MOP. Any simple MOP is subject to a search of its content frame. This means that the basic organizational structure of such MOPs is a frame of information that can be used to impose a number of critical connections from the MOP being searched to information vital to that MOP.

Simple MOPs have a set of conditions that define what information is present in a MOP. We call this information the MOP's content frame. Thus a given MOP can be expected to have strands corresponding to:

a. reasons for the MOP existing if it's a state; reasons for doing the MOP if it's an action

b. enabling conditions for the state or action

c. results of doing the MOP if it's an action, or changing the state if it's negative, or not changing it if it's positive

d. standardization - normative methods of achieving or satisfying the state

e. goal related - what goals the state or action relates to and which it affects

f. associated states

g. associated actions
these last two take care of many associative phenomena by linking MOPs.

Searching the content frame for DOCTOR asks the following questions that are significant for the construction of the DOCTOR super script.

1- What event sequence(s) is the DOCTOR MOP normally part of? (This is answered either by attaching DOCTOR to a strand of an event sequence of another MOP, or by directly answering the questions:
What actions initiate DOCTOR?
What events normally follow DOCTOR?)

2- What are the preconditions for doing DOCTOR?

3- What standard actions does a doctor do?

4- Why does a doctor do DOCTOR? (i.e., the results for the doctor)

5- Why does a patient do DOCTOR? (i.e., the results for the patient)

Each of these questions is answerable by information stored directly in the DOCTOR MOP's Content Frame. In other words, these answers need not be reconstructed; they are available directly through the Content Frame of the MOP. However, the answers do point to other MOPs and it is this fact that allows us

to begin to construct the doctor super script. The answers to the above questions are of two kinds, procedural and stative. That is, the kind of information that is relevant here is both the states of the doctor and patient before and after the visit and the events that lead up to, follow and govern the flow of the visit. Thus, for DOCTOR the answers to the above questions are:

1 - DOCTOR actions are performed in PROF HOME VISIT or
    PROF OFFICE VISIT

2 - doctor is at same location as patient
        (satisfied in PHV by doctor PTRANS to patient,
                   in POV by patient PTRANS to doctor)

3 - $examine, diagnose, prescribe-medicine,
      prescribe-care-procedures

4 - see JOB MOP and MAKE-CONTRACT MOP

5 - ill health and GOAL MOP: P-HEALTH (see FIX PROBLEM)

The doctor super script is constructed by combining all the MOPs referred to in answers to the above questions according to Temporal Precedence Search (TPS). Temporal Precedence Search sorts through the MOPs provided by time and enablement criteria as needed to follow a new situation. The super script, including all of the possible temporal sequences allowed by the active MOPs, need never be completely formed at one time. Whole scenes in the superscript may be missing from any given story or sequence of events to be understood, and only one of many possible action sequences will ever be needed for any scene that is present. Thus, construction of the complete superscript is unnecessary. What does exist is the set of active MOPS, and their known interconnections, which can be combined as needed to

understand aspects of stories in the domain of the super script. TPS is therefore a procedure for tracing temporal paths through these active MOPS.

Once a MOP has been found which provides a temporal sequence (either the original MOP or the answer to question 1 above), the super script is constructed by (1) starting the sequence with any actions needed to initiate the sequence in the MOP, plus actions from other MOPS needed to satisfy preconditions of the current MOP, (2) filling in the empty slots in the sequence given by the current MOP, (3) ending the sequence with any standard follow up actions, and (4) merging the completed sequence with sequences built by the other MOPs which are activated because they partially overlap with the one under construction. MOPs overlap when their strands twine, or share a single event in the sequence being constructed.

In the story above, the first sentence activates the DOCTOR MOP. The answer to the question "What event sequence contains DOCTOR?" points to the PROF OFFICE VISIT MOP, since the first sentence of the story mentions <u>going</u> to the doctor. That fulfills a precondition of PROF OFFICE VISIT, not PROF HOME VISIT. (In addition, POV is the normal default procedure for seeing a doctor.) This MOP contains information about the similarities found among the offices of service professionals, and the temporal sequence of scenes which the patient or client follows when visiting such an office. The sequence described by the PROF OFFICE VISIT MOP is:

INITIATOR- MAKE-APPOINTMENT

PRECONDITION- [be there]

SEQUENCE-
  ENTER + WAITING ROOM + ENTER OFFICE + [get service]
            + LEAVE OFFICE + (MAKE NEW APPOINTMENT) + EXIT

FOLLOWED-BY- [go elsewhere] (after EXIT),
              [get bill] + [pay bill] (from MAKE CONTRACT)

The empty slots in the sequence above are the items in brackets. Items not in brackets are scenes which are unique to this MOP, and are tied directly to episodes remembered from past experiences. These empty slots are filled by other MOPS, or scripts.

The slots represented by [be there] and [go elsewhere] are both normally filled by the LOCAL TRAVEL mop which points to standard script solutions such as $BUS, $CAR, $WALK, and $SUBWAY for getting to and from specific places. However, since the story does not get more specific on this point, these slots will remain empty. Should it become necessary to fill these slots, they do contain information about the destination or departure point which the LOCAL TRAVEL MOP can use in determining which specific script should fill the slot.

The next empty slot in PROF OFFICE VISIT is the [get service] slot. Responsibility for filling this slot is left to the MOP which activated PROF OFFICE VISIT, in this case the DOCTOR MOP. The standard actions of a doctor performing his service will be recognized as normal at this point in the event sequence being constructed.

PROF OFFICE VISIT MAKE CONTRACT

MAKE APPT + [get there] + WAITING ROOM + [get service] + [go away] + PAY BILL

$DOCTOR

Many strands of the PROF OFFICE VISIT MOP are twined with strands from other, more general MOPS, which actually contain the information needed to complete the superscript. MAKE APPOINTMENT and [get service], for example, are also part of the general MOP MAKE CONTRACT.

The normal sequence under MAKE CONTRACT is

[agree to contract] + [deliver service] + GET BILL + PAY BILL

[agree to contract] is twined with [make appointment] in POV and [deliver service] is twined with [get service]. To complete the superscript, the temporal sequences which these two MOPs contain must be merged, as much as possible. Thus, the normal temporal ordering of GET BILL and PAY BILL in the resulting superscript are due to their position in the temporal sequence provided by MAKE CONTRACT. The result is that GET BILL and PAY BILL may be expected to occur anywhere after [get service].

The construction of the rest of the DOCTOR super script makes use of the other questions in the Content Frame for the DOCTOR MOP. Recall that the POV MOP was brought in by looking at the "part-of-sequence" strand of the DOCTOR MOP, i.e., the answer to question (1) above. This brought in most of the temporal sequence, but did not specify all of the preconditions for the

sequence, nor did it give the motives of the characters, both of which will be needed should anything abnormal occur in a story about going to the doctor.

The precondition for a patient seeing a doctor is that the patient is sick. This state is a MOP as well, and has an INITIATES-ACTION strand pointing to FIX-PROBLEM and a standard solution strand pointing to the DOCTOR MOP. FIX-PROBLEM's temporal sequence has one strand filled by the MAKE CONTRACT MOP, with the patient (the one who had the problem) in the role of the actor requesting a service. This defines the patient's role in the doctor/patient contract.

Now that we have seen how the super script is constructed it is time to take a look at one MOP in detail; we shall look at POV. In order to use POV in constructing the doctor super script, we got to it by having marked in the DOCTOR MOP that its initiate strand entailed a POV. So, one thing we know about POV is that it is linked to DOCTOR by a sub-sequence strand. Clearly, this is not the only MOP to which it is so linked. Any other MOP that specifies a set of events normally taking place in an office that people travel to in order to avail themselves of some service, would also be so marked. So, lawyer, dentist, accountant, and so on would also have such links. This immediately brings up the question of whether these strands that link POV and various other MOPs are traversable in both directions. It seems fairly obvious that a system that allowed such strands to be traversable both ways would get out of hand

fairly quickly. Further, there is no evidence that says that we can easily name all the kinds of people who have such types of offices. What is more likely is that we have some method of searching for professionals and then seeing if they have such offices.

So the first thing we know about POV is that it has a large number of links to it from various MOPs that call it up. The second thing we know about POV is that it provides a set of scenes to help in the construction of the doctor super script.

The main job of POV is to provide an ordering relationship on a set of scenes, not all of which come from POV directly. POV is first and foremost an orderer of temporal precedences, i.e., an organizer of information found elsewhere. The scenes that comprise POV are of two types, those that belong only to POV and those that are shared with another MOP. PAY BILL, for example, is shared with MAKE CONTRACT, which as we have said is also active here. This sharing can be taken quite literally. That is, different aspects of memory episodes about bill paying will exist in memory as part of the MOPs from which they came. WAITING ROOM on the other hand will contain actual memories because it is a scene that is not shared by any other strand. It is this property of lacking overlaps with other MOPs that (somewhat counterintuitively) causes memory confusions. The reason is as follows: since WAITING ROOM is not shared anything happening in it is remembered as happening in it quite clearly. But, since a great many MOPs use POV as their setting, a great

many MOPs are leaving part of their episodic content in WAITING ROOM which they all rely upon for construction of their super scripts. As we have said, the strands they use to link to POV are not two way. Thus, they all use WAITING ROOM as a resource but do not get back any of the resultant memories. These memories stay in WAITING ROOM. Thus, we get memory confusions on access via Professional type MOPs.

An important point here, then, is that scenes that are not shared at a higher level by another MOP are terminal, which means that we can expect to find a large number of real episodes stored in those scenes. As we have said, one of the important functions of POV is to serve as a store for particular memories. Since only terminal scenes can grab up particular experiences and store them we must focus on WAITING ROOM. An experience in a waiting room of an office will get disembodied from the rest of the visit in memory. What happens in the waiting room will be stored in the WAITING ROOM scene of the POV MOP but the actual consultation with the doctor or lawyer himself will be stored with a different MOP.

One important feature of a TPS through a MOP is that it serves to identify both content strands and empty strands of the MOP. In POV for example, WAITING ROOM is a content strand. That is, it has a great deal of information attached to it such as what a waiting room looks like, what is in it, what happens there, and so on. The [get service] strand, on the other hand, is entirely empty. It serves merely as a kind of place holder,

its only content being what is connected temporarily to it on either side. This is where what we are now calling the $DOCTOR or $DENTIST script comes into play. These scripts contain only the most specific information concerning what a doctor does in filling [get service] for a patient. The DOCTOR script is thus only a small part of the DOCTOR MOP. Thus, scripts are very particular structures about a situation that can fill in an empty strand in a MOP.

We can now take a look at how a story such as the one given above should be processed. As we have said, the first sentence sets the DOCTOR MOP in operation. This in turn activates PROF OFFICE VISIT, which defines the sequence of events to be expected. Now when the sentence,

"While I was reading a magazine I noticed that a patient who arrived after me was being taken ahead of me."

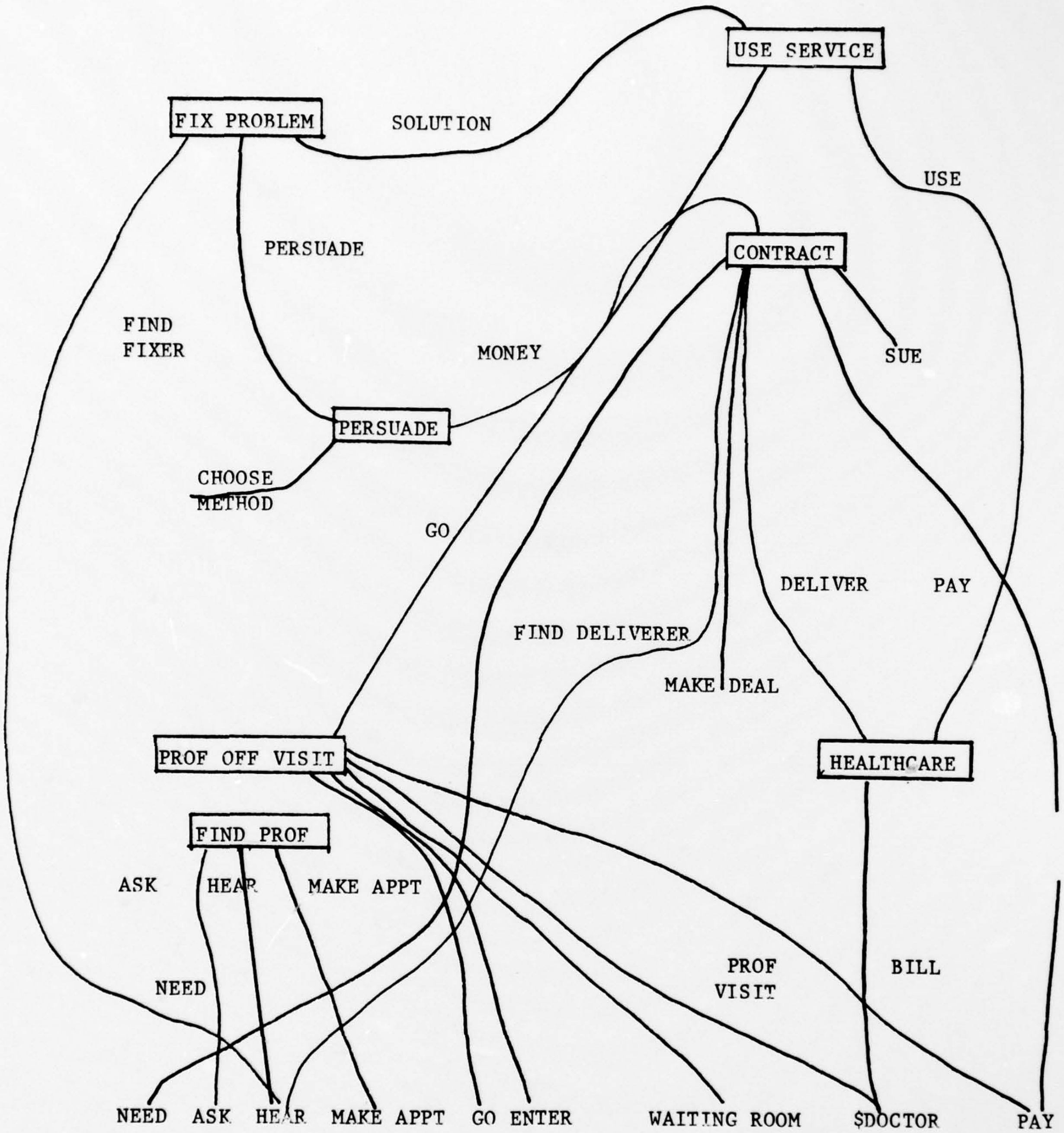
is encountered, it can be interpreted in terms of knowledge stored with the POV MOP for WAITING ROOMS, since that is the first (and only) scene found by TPS which can normally include reading magazines. Also to be found with the WAITING ROOM scene are pointers to the reasons for doing the scene, in this case, knowledge of the social convention of queueing or "waiting one's turn". Interpreting the remainder of sentence two above in terms of knowledge of that ordering convention results in the recognition of a violation of that convention by the doctor.

The final sentence,

"I am going to get even by not paying my bill for six months!"

refers to the PAY BILL scene of MAKE SERVICE CONTRACT, which was activated by TPS as described above. Here, again, a violation of the social conventions for an action is described, as well as a reference to a high level structure, REVENGE, which is used to interpret the relation between the two violations. (REVENGE is not a MOP. It is a TOP, a structure like a MOP but at a different level. TOPs will be discussed shortly.)

As we have seen, there are a great many structures relevant in a story about a visit to the doctor. Some of these become relevant because MOPs can themselves be <u>strands</u> of other MOPs. Also there is a <u>twining</u> mechanism that can cause strands from many MOPs to fill the same empty strand in another MOP. Here is an illustration showing the interconnections of the MOPs relevant for a doctor's office visit:



The above is a sketchy view of the MOPs that contribute to providing all the expectations necessary to understand what is going on in a visit to a doctor's office. The function of each of the MOPs used here is to provide information relevant to the

part of the overall situation for which the MOP is relevant. What is finally produced in the end is a super script which looks very much like any given selected path through a script of the kind we discussed in Schank and Abelson (1977) and used by Cullingford (1978). A superscript functions in the same way as what we used to call scripts did, except that it has been constructed from memory rather than having been retrieved from memory. One consequence of this is that there is no limit to what can and cannot be a superscript since there are such a large number of possible combinations of the various pieces of the various MOPs. In addition, there are no tracks in a superscript. Neither is there a memory structure that corresponds to the superscript. The superscript is merely the output of the process of combining MOPs in order to build a processing structure that will aid in understanding a situation. It in no sense exists in memory except for an instant as it's being constructed. Memories are absorbed by the MOPs that were connected to their appropriate pieces.

Reliance on a MOP can also often tell us what information is irrelevant. Thus, PERSUADE has a strand for CONVINCING which connects to CONTRACT which connects to HEALTHCARE. Thus when we understand a doctor visit, we need not wonder how the doctor got convinced to help out. We find that an implicit contract has been made (it's seen to be implicit because the "make deal" strand is left dangling) and that no actual convincing strategy had to be used. The replacement of a MOP strand by an entire other MOP serves as a stylized way of accomplishing the filling

of a strand. That is, we need not plan when a standard method is available for a solution.

11. MAP Search

Since MOPs represent the main type of memory structure available for the storage of information, the issue of how such MOPs can be searched is of major importance.

Temporal Precedence Search (TPS) was discussed earlier. Its main use is in building a super script for use in processing information about a situation. TPS is also used when answering questions about what happened in a previously processed episode. Although she did not use TPS in the question-answering algorithms that she designed, the work of Lehnert (1977) relates directly here. The construction of "ghost paths", which was discussed by Lehnert for answering questions about non-existent events, would rely heavily on TPS if it were done in the most general way possible.

Map search (MAP) imposes an external structure on a MOP and reconfigures it according to the structure of the MAP being used. Thus searching a museum MOP by MAP search produces a list of museums according to cities or states or whatever if a geographic MAP is used. Other MAPs include corporate structure charts, team positions on a sports team, and the various sections of an experience, i.e., classes, teachers and years in school or types of activities in a summer camp. The use of a MAP, then, is to sort out the strands of a MOP according to well specified externally imposed dimensions.

Clearly only a very few MAPs are useful for most MOPs, so part of the MAP search strategy is finding the names of the MAPs useful to start the search of any given MOP.

One of the most valuable kinds of MAP searches is the kind that performs what semantic memory systems do by ISA links. To find all the strands of the HEALTHCARE MOP, for example, we could say that you do an ISA search for all the types of HEALTHCARE that there are. However, this kind of ability seems unlikely and difficult. We cannot really retrieve all the members of a set very easily (see Schank, 1975). A MAP search on the other hand applies an appropriate MAP. For HEALTHCARE this might be a MAP of the body. With this MAP in mind we can then check (by a sort of generate and test) to see if there are strands for foot doctors, head doctors, chest doctors, and so on. These MAP searches find the set memberships according to different criteria (that of the MAP) for a given MOP.

A very common kind of MAP search is the Content Frame Map that we described above. A Content Frame is a kind of pre-applied MAP that provides specific information about the content of that MOP. Every MOP has a basic structure to it and that structure is called its content-frame. Applying the content frame is thus a trivial procedure to implement, requiring no more than finding the frame and looking at it. The serious question here is, what is the content-frame for any given MOP? The content frame for WAITING ROOM is of a different nature than the one for DOCTOR. It is much more visually or physically oriented,

corresponding most closely to what Minsky (1975) called the "room-frame". Obviously a complete set of content-frames will have to be worked out in any usable theory of memory.

12. Processing With MOPs

Memory Organization Packets serve not only as the basis of memory, but as the basis of processing. As we have said earlier, processing and memory must employ the same structures. In order to understand an input it is necessary to find an episode in memory that is most like the new input. (As we noted, reminding is one way of noticing that such things are happening.)

Processing an input means finding a relevant memory piece. When such a piece is found, expectations are created that come from all the pieces to which the initial memory piece is connected. Thus, when we receive an input we look for a relevant MOP. Upon finding this MOP we create expectations at every level to which that MOP is naturally connected. Thus, expectations from scripts that have been activated create demands for certain conceptualizations. Expectations are simultaneously generated from all the MOPs that the relevant script fills slots in, as well as from the "meta-MOPs" that those MOPs filled the slots of and so on. (A meta-MOP is a MOP whose strands are exclusively filled by MOPs.)

Some of these expectations are extremely high level. For example, upon noticing that someone was trying to fix a drain, we might begin to expect to receive inputs or have to make inferences relevant to: payment for plumbers, asking for help in general, the consequences of failing to fix the drain properly, the consequences of success and so on. But we also would expect

tools, and water, and turning actions, and make other low level predictions. These come from the various levels of MOPs that are applicable. Such predictions are useful in processing since they help to make sense of what is going on. They also bring to bear many particular episodes in memory that have been stored at each of the activated MOPs. In addition, these MOPs soak up the new inputs that are relevant to them, altering the MOP that has soaked it up, as well as breaking up the remembrances of the episode being understood into its MOP-related pieces.

To illustrate how some of this works, consider a story beginning: "My drain pipe was overflowing." Now for our purposes the point is not whether this is the first line of the story or not. Rather, it is important that this simply be an input to a cognitive system. The fact that you might hear such a thing in everyday conversation is important also. The questions we need to address are:

1 - What comes to mind upon hearing such a sentence?

2 - What structures are being activated in memory that cause such things to come to mind?

3 - What state is the mind in after having received this input?

At Yale in recent years, and among researchers in general concerned with scripts or schemata, it has seemed plausible to answer these questions with something called the "plumber script". Such a script implies that any body of knowledge can be a script. Clearly a body of knowledge about plumbing can be assembled from the various corners of memory in which it resides

so as to create such an entity as a plumber script. One issue is whether such an entity pre-exists in memory or is constructed, and if the latter then the real issue is "constructed from what pieces by what method?" A second issue is, where are our episodic memories to be found that will help us respond to what we have heard? It seems unlikely that every experience we have had with plumbers is organized by $PLUMBER. Clearly a great many memory structures are likely to be active.

We have so far taken the position that to have precompiled chunks of memory such as a plumber script does not explain the facts of memory with regard to recognition confusions, memory searches, and forgetting based upon the breaking up of an experience into chunks. A great deal of information can be retrieved about plumbers (what a plumber is likely to wear, the estimated size of the bill, etc.), that is in no sense a part of the script. So it seems safe to say that some reconstruction is going on; various pieces of memory are being searched when an input is being processed. In our discussion we will assume that there is no plumber script in anything but the simplest of all forms, and that the main problem in responding to an input such as the one above is the accessing of the memory structures relevant to the creation of the plumber super script.

What kind of high level structures might be relevant to "My drain pipe is overflowing"? Clearly it is relevant that drains are part of sinks or houses. This fixes the general location of the item in question. Such information is part of the meaning of

"drain". It is unlikely that there would be a "drain MOP" available with that information in it. The existence of such a MOP implies that memories about drains are organized together in one place. This seems unlikely. However, there is nothing immutable about what can be a MOP. Different individuals with different levels of expertise are likely to have different needs in memory organization.

"Drain" points to information about bathrooms and kitchens, etc. Such information is stored by using "room frames" as we said above. Such frames contain primarily visual information rather than episodic information (although again this is possible). The visual information attached to the room frame here is helpful for understanding future inputs such as: "To fix it I sat on the toilet", or "The overflow ruined $20 worth of cleanser stored underneath". Such statements would be quite impossible to understand without these frames active and ready. But such frames are not MOPs, they are just, on occasion, used by MOPs.

One way they are used by MOPs here is that, since these rooms are parts of houses, the combination of the implicit house and the possessive "my" causes information about HOMEOWNERSHIP to be activated. HOMEOWNERSHIP has information in it derived from preservation goals (P-GOALS, see Schank and Abelson, 1977) and among other things, points to the FIX PROBLEM MOP.

Of course people have drains in places they rent as well. This possibility is activated in absence of knowledge to the contrary by activating D-AGENCY (Schank and Abelson, 1977). D-AGENCY points to knowledge about AGENCY relationships (which is what "Landlords" are) so that HOMEOWNERSHIP can still be used although it would be mediated by D-AGENCY.

Until we see 'overflowing' we do not know what is being told to us really. But, after we have seen it, a great many structures must become active. First, the conceptualization that is to be constructed here contains empty CD slots for what object is being PROPELed led (which comes from 'overflow') and to where. The OBJECT defaults to "water" by consulting the "normal contents" part of the conceptual dictionary item for "drain". The "TO" slot is filled by consulting the relevant frames, in this case some candidates are "in house", "on floor", and "on carpet".

The activation of FIXPROBLEM causes the attempt at the creation of a solution (one of the TPS search's uncovered steps in FIX PROBLEM). FIX PROBLEM has as its strands FIND FIXER, PERSUADE, and SOLUTION. Each of these, as it turns out, is a possible topic of conversation where the first input is our above sentence. Thus we might hear:

a - I know a good plumber.
b - My, that's going to cost a lot of money.
c - Have you tried Drain - Fixing Drano?

The fact that all of these are quite possible as responses here is an important indication that all of these structures are

active in the mind of the understander of these sentences. To further test the validity of the active high level structures in this way, consider other possible responses based on the other structures given above:

d - That sink of yours has been rotten for ages.
e - I told you not to get such an old house.
f - Boy, isn't it a pain to own a house?

Each of these is perfectly plausible as a response. We attribute this to the fact that some high level memory structure would have had to have been activated by the input. What other kinds of statements might be acceptable here? Some candidates are:

g - Oh, isn't that awful.
h - Did you have to stay home from work?
i - Water can be awfully damaging.
j - Do you know how to fix it?
k - Would you like to borrow my Stilson wrench?
l - And with your mother coming to visit, too!
m - This has certainly been a bad month for you, hasn't it?

Assuming that these too are all legitimate, what structures do they come from?

The ultimate question here then is what kinds of MOPs are there and how many of them are likely to be active at any given time? It seems plausible that the following high level structures are likely to be active during the processing of our input sentence:

JOB; FAMILY RELATIONS
HOMEOWNERSHIP

FIX PROBLEM; PERSUADE
USE SERVICE

PROF HOME VISIT
FAMILY VISIT TO HOME
FIND PROF
MAKE CONTRACT

$PLUMBER

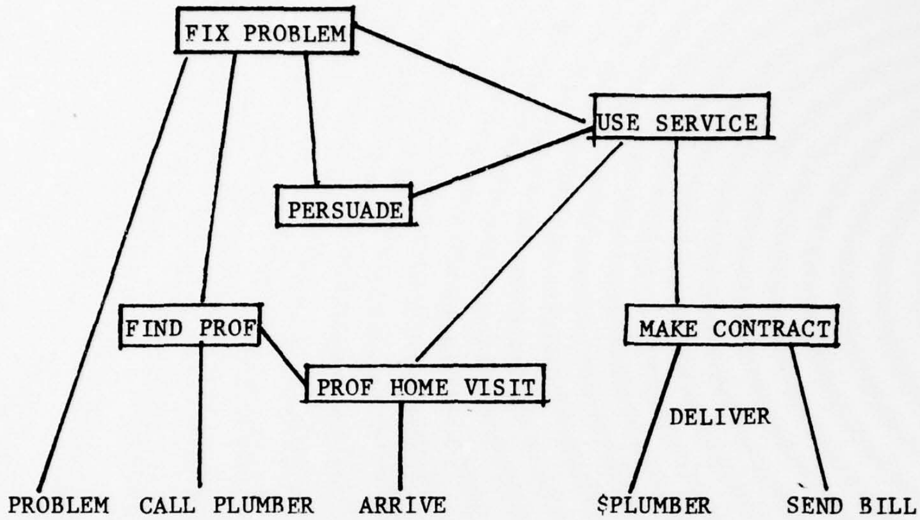
Are all these structures MOPs? Some of them clearly are and some of them fall into a rather grey area. Recall that a MOP is an organizer of information that can be used by a TPS to create a superscript. Recall further that MOPs serve to organize terminal scenes that have within them a backbone of a sequence of events that are episodes from memory organized in terms of that backbone. These terminal scenes are either script-like (in which case they contain deviations from the normal flow of the script encoded as actual memories) or else they are locative in nature (in which case they contain actual episodes that are organized in a non-event based manner, possibly visually). Thus, a MOP is an organizer of terminal scenes or actual memory episodes. By this analysis, PROF HOME VISIT, FAMILY VISIT TO HOME, FIND PROF, and MAKE CONTRACT are all MOPs. They each organize terminal scenes such as PAY, PHONING FOR AN APPOINTMENT, FAMILY DINNER, and so on. As we have said, these terminal scenes are where actual memories are to be found.

We also know that FIX PROBLEM, PERSUADE, and USE SERVICE are meta-MOPs. That is, they organize MOPs and contain no memories themselves, but they can be searched by TPS.

This leaves us with JOB, FAMILY RELATIONS, and HOMEOWNERSHIP as active knowledge structures that do not fit in with our previously established definition of MOPs and the structures that both organize and are organized by MOPs. What are these structures and how do they differ from MOPs?

The first thing to notice about these labels is that we have a great deal of information about them in our memories. In fact, we have so much information and it is of such great importance to us (i.e., it concerns our high level goals) that to begin to think that we can break such structures down into MOPs that organize terminal scenes that combine according to TPS is absurd. There is, for example, a JOB MOP that contains scenes about applying for jobs, getting paid, terminating employment, and so on. But there is a great deal more information about one's job or knowledge of jobs in general that could not be neatly contained in the JOB MOP. The point here is that such information is at a higher level than that of MOPs. We shall next begin to discuss the structures that might contain that information.

The MOPs that we have specified and the other high level structures that we have not specified relate as follows for this story:



All of the MOPs mentioned here are capable of making useful predictions about what is going on in this situation. The big questions then, are exactly when such predictions are made, how they are called into play in processing, and from where they come.

13. TOPs

We are now ready to look at the kinds of high level structures that are available to memory. To begin, of course, we have scripts.

Scripts conform to the terminal scenes of MOPs. They are subject to TPS, produce CD's and contain memories, so they are a special kind of MOP. However, MOPs tend to organize information in general about an area and thus one level of sub-organization in MOPs are the methods of filling the various strands of the MOP. That's what scripts are: standardized memory chunks that are particular methods of filling one or more strands in a MOP. Thus, $DENTIST, $PLUMBER, and $RESTAURANT all fill DELIVER in MAKE CONTRACT. They also fill other parts of MAKE CONTRACT in specified ways as well (the PAY strand is controlled by them, for example). Organizing scripts then, we have MOPs and organizing MOPs we have meta-MOPs. What comes next?

Consider, FAMILY VISITS, a structure we used in passing in the last example. FAMILY VISITS are clearly idiosyncratic, but that does not lessen their validity for any given individual. Suppose we had a family whose visits usually went as follows:

FAMILY ARRIVES -> HUGGING -> PRESENT GIVING ->
FAMILY NEWS TELLING -> DINNER ->
FAMILY FIGHT -> LEAVE IN ANGER

If such a well defined structure exists for an individual, that is, if his family visits usually conform to that kind of flow, then for him, FAMILY VISIT is a MOP. So, the first thing that we notice is that there is nothing immutable about what can be a MOP.

Even more significantly, people are capable of compiling experiences in their own idiosyncratic ways. That is, one can be reminded of all sorts of disparate events by new inputs. These remindings occur according to organization packets that have been previously constructed, and while not directly related to the new experience, nonetheless are elicited by it. For example, suppose that upon hearing a story about a family visit such as the one outlined above, you are reminded of a recent diplomatic visit of a head of state who arrived happily but left threatening war. Such a reminding experience seems quite natural, yet there is nothing like FAMILY VISIT about this scene. Considering these two events, we can now ask what kind of memory packaging might have caused these two stories to elicit the same processing node.

We have now come full circle from the reminding issues we were discussing previously. The problem of reminding structures that we had before was solved, we guessed then, by using a Goal Subsumption failure node in memory for processing, memory storage, and reminding. Goal Subsumption failure, then, would have to somehow point to some kind of structure under which information relevant to it would be found. Let's take a look at how this might work.

Notice that we have two different kinds of reminding phenomena here. In the FAMILY VISIT case, we have a reminding phenomenon similar to the legal seafood line mentioned earlier. That is, we have one episode which requires the backbone of a terminal scene of a MOP for its processing; at the end of the most relevant deviation from the backbone, we find an episode that one is reminded of. But, for the Goal Subsumption failure case, the reminding is not from an input episode to a previously processed individual episode, but rather is from an input episode to a previously compiled point of view. That is, the reminding that occurred was not a reminding about a particular episode in gas stations, but rather a reminding about the absurdity of buying gas in small quantities in general. Thus there must be an organization point corresponding to Goal Subsumption failure that contains pointers to specific episodes and previously compiled conclusions and generalizations that are related to that organization point. Such organization points are built up over time according to sequences or patterns of events rather than according to specific episodes.

For example, "unrequited love", or "communist takeovers", or "revenge against teachers" might be examples of such organization points. We call such structures TOPs for Thematic Organization Points. A TOP organizes compiled sequences of events that are not broken down and stored in terms of MOPs. That is, TOP memory is not reconstructive. If you have a bad time with a girlfriend that takes place over a long period of time and causes other problems in your life, you do not experience recognition

confusions. You do not forget which girlfriend it was or what bad experience it caused. This is because these experiences are stored as chunks rather than as disembodied scenes. Of course, these chunks can make use of MOPs that refer to terminal scenes. Thus, there can still be confusion over exactly which restaurant you had the fight with your girlfriend in, but a similar confusion over which girlfriend it was implies a girlfriend MOP which is likely to exist for only the most unusual of individuals.

TOPs thus organize chunks of episodes that have in common some overall theme or goal related point. Interruptions in the achievement of a high level goal can bring to mind similar interruptions organized in that TOP. That is, during processing we are tracking the goal-fates (Schank and Abelson, 1977) and the thematic relationships. In processing along these lines, we use structures similar to the backbone used for script-based processing. Thus, actual memories will be triggered by going down a path in a goal-fate analysis that has some unusual ending. TOPs thus are basic organizers of memories and sources of predictions in processing in the same way that MOPs are. TOPs also contain information that is not part of a sequence of episodes in memory. TOPs contain generalizations and conclusions gleaned from experiences. These too are organized according to the goals they are related to.

We can now return to the problem of the reminding in the family visit described above. One possible answer to this problem would involve the use of both a VISIT MOP and an ARGUMENT MOP which might be connected by an INTERFERENCE link. The problem with this is that it requires the construction of an ARGUMENT MOP, and it is unlikely that ARGUMENT would be a MOP for any individual. It does not seem easy to answer questions such as "what arguments have you had recently?" What is easier is a cued recall such as "can you recall an argument that you had with your mother?" This implies that arguments are searched for by specifying the MOP to search in first. Thus, questions about arguments during visits should be easier to answer than questions about visits that occurred in the context of an argument. VISIT is clearly contextual for ARGUMENT. That is, VISIT is a MOP. Just as we showed in the restaurant script given in detail earlier, argument is an INTERFERENCE path within the VISIT MOP that is a repository for memories about arguments that interrupted visits. This, of course, implies that without supplying a context, arguments cannot be searched directly. That is what we are claiming when we say that ARGUMENT is not likely to be a MOP.

This brings me to another crucial point. It seems on the surface that an interference itself can be a MOP. That is, sometimes the very fact that an interference has been encountered in a given MOP can remind one of a similar interference in a different MOP. Thus, for example, the head of state having an argument on a visit cannot only remind one of arguments with

one's mother on a visit, but it could also remind you of a rainstorm during a picnic. To see what I mean by this, it is important to recognize that any given input can be processed on many different levels simultaneously. That is, both MOPs and TOPs are active at once. The rainstorm reminding is due to the interference of goals in a given context and that kind of reminding is accounted for by TOPs. To see this imagine a context in which our supposed head of state visit took a great deal of planning, went smoothly at the outset, was expected to have great ramifications for future efforts at consummating an important deal, and then went away because of some capricious act under the control of no one in particular that caused the argument and the subsequent diplomatic rift. Clearly the same sort of thing could be happening at a well planned picnic that was intended to have important personal or business ramifications and then got fouled up because of the weather which in turn permanently ruined the pending deal. The fact that one such event can remind you of such a clearly dissimilar event in terms of the MOPs involved clearly indicates that there are TOPs operating at higher levels of memory organization.

14. Intentions and TOPs

At the interface between TOPs and MOPs, we find Intentions. Intentions are the highest level MOPs that there are. They are grounded in MOPs (like meta-MOPs) but they actually contain memories. They tend to organize MOPs in the same way that MOPs organize scenes. However they also have an additional role, namely they are the low level entities that are most commonly organized by TOPs.

Some examples of Intentions are I-TERRORISM, I-ROMANCE, I-VACATION, I-BUSINESS-DEAL. Intentions are too high level to be scripts, but are more specific than goals. Furthermore, the information that they organize usually provides a setting for a story or whole episode since that information relates to a fairly high level set of goals. Frequently, an Intention organizes together a set of scripts all in service of a common high level goal. Thus, when an Intention has been determined, the construction of a superscript usually follows from it rather easily. For example, I-TERRORISM organizes $KIDNAP, $AMBUSH, and $BOMB among others. Intentions are essentially one step away from goals. We know what the goal dominating any given Intention is. We know why people engage in I-ROMANCE or I-VACATION without a great deal of uncertainty. Of course, there is always the possibility of multiple goals, or entirely unusual goals dominating a given Intention. This is why an Intention is not itself a goal. If the goal dominating I-ROMANCE is a kind of revenge, that does not change how I-ROMANCE functions. (It

might, of course, alter some elements in I-ROMANCE.)

Intentions function similarly to meta-MOPs in that their strands are filled by MOPs. However, we might expect to find actual memories stand directly under an Intention, whereas we do not find memories directly in a meta-MOP. Another way of saying this is that one can recall romances one has had or trips one has taken when asked to do so but responding quickly to "have you ever fixed a problem?" is quite a bit harder.

Intentions are clearly subject to TPS, since their function is to organize the control of events. They also have a content frame that can be searched. We know a great many "facts about" TERRORISM or ROMANCE. They are subject to MAP search as well. "Did you ever vacation in the Caribbean?" is likely to help elicit a forgotten vacation. Thus INTENTIONS are MOPs. We call them I-MOPs.

One very important property of I-MOPs is the way they relate to TOPs. One of the first things that we can say about TOPs is that they are structures that people can do without. By this I mean that it is not necessary to organize experiences at this level in order to understand the world. TOPs provide a greater degree of understanding or a greater insight into patterns of what is going on. Often these patterns can be solely in the mind of the beholder. Indeed, such patterns can be neurotic and even psychotic (both PARRY, (Colby, 1975) and POLITICS, (Carbonell,1979) used them). TOPs are of the form: first this kind of thing happens, then I have noticed that this follows, and

then that, and finally that. The "thises" and "thats" in TOPs are frequently Intentions, although they can be any combination of MOPs. So, for example, the plot of Romeo and Juliet is a TOP, whose basic structure can be used for West Side Story, and so on. People can recognize one of these as an instance of the other. Their doing so is an instance of using TOPs.

Since TOPs are grounded in I-MOPs they tend to describe long term situations leading to the satisfaction of higher level goals. I-ROMANCE is composed of various MOPs such as $DATING, $RESTAURANTS and so on. Similarly, the pursuit of a job promotion, or position of prominence in a community are instances of TOPs. TOPs thus include much of what Wilensky (1978) called goal progressions.

TOPs can also organize across Intentions and it is that ability that is a crucial part of memory. The "I planned it so nicely and it got ruined by something I couldn't control" TOP is what governs the picnic and visit stories above. Ultimately these are seen as similar or not depending on whether there is a TOP available at the right level of abstraction to account for the new event. That is, TOPs are highly idiosyncratic. One can abstract out any pattern from one's experiences. The question is whether that pattern will ever repeat and thus be of some predictive value.

TOPs thus organize all the bizarre idiosyncratic patterns we choose to notice. They represent the ultimate in the human ability to abstract out significant generalizations from one's

experiences. That is, they represent passive recognition of what is happening around us. Thus they represent our view of what other people's plans or random combinations of circumstances might bring about.

But, a sequence of events can be controlled by an actor who had a goal in mind. Such a sequence, if it has been thought out in advance, is a possible TOP in the mind of the actor. That is, memories of past such sequences would likely reside in such a TOP and would help to control events in the sequence. Such TOPs are goal-oriented in the sense that the events are in the service of a goal.

Thus, one basic division of TOPs that can be made is between those that organize patterns in pursuit of goals observed from the outside world and those that are useful in organizing one's own experiences where the goals are more readily available. The class of TOPs that are organized around one's goals are called Designs, and come in two varieties, Grand and Small. Grand Designs have actual memories stored under them, although as with all TOPs these memories are not very specific, because the MOP-related material has been remembered elsewhere. What is left is the goal oriented material stored in terms of event sequences that occur over long periods of time, and in terms of I-MOPs. The actual events that made up the I-MOPs might have to be reconstructed to be remembered (as with any MOP).

Grand Designs are in service of high level goals like, "take over the world" or "become President" or "subvert the enemy". Grand Designs are thus plans of action for complicated attacks on a problem, intending to converge on a long term solution. Clearly one man's Grand Design can be a TOP in his opponent's head as well. But these are remembered quite differently. If my enemy intends to subvert people, I need not know or even think about why he is doing it and what various low level issues (such as motivating his agents) he has to deal with. Grand Designs govern a flow of control over precisely those issues. Thus a Grand Design is subject to TPS.

Grand Designs are collections of common event sequences and intentions, together with various arrangements of goals that explain or predict outcomes of broad behavior patterns. Grand Designs represent a sophisticated analysis of why people do what they do - sort of a grand plan of the universe. For example, one person's perception of another's intention in being nice to somebody to use them for some later purpose is one instance of a Grand Design. The "Goldwater program" uses such grand designs, although they were originally called master scripts by Abelson (1965) and beliefs by Carbonell (1979).

To understand the place of an event in a Grand Design requires a sophisticated understanding model. "Naive people" often do not ever recognize such Grand Designs. Grand Designs occur in relation to high level goals ("take over the world", "corner the gold market", "become president of the company").

Small Designs explain lower level goal pursuits such as "seduction" or "flattery".

However, before we get into the issue of Small Designs and other higher level structures, it is important to outline an example that illustrates what we are talking about.

Looking back at a dentist visit from the perspective of the different kinds of structures and the knowledge that would be contained in them, we find:

A trip to the dentist and all its associated events is an experience at the event (EM) level of memory. To understand this event, it is necessary to have information about dentists, tooth pulling and so on that will be found in scripts at the GEM level of episodically generated facts. At the SM level, the relevant MOPs are PROF OFFICE VISIT, MAKE CONTRACT and so on.

At the Intentional Memory level the I-HEALTHCARE I-MOP has been activated. Its purpose is to fill in the strands of MAKE CONTRACT, PROF OFFICE VISIT, and so on with HEALTHCARE information. Dominating I-HEALTHCARE is the goal P-HEALTH. No memories are stored with simple goals such as this. (For more about P-HEALTH, see Schank and Abelson, 1977).

However it is certainly possible to imagine that P-HEALTH is not the dominating goal here. It is easy to imagine one doctor going to another simply to see how the competition is doing, or a neurotic going to the doctor for companionship. In these cases, all the MOPs and I-MOPs are the same, but the goals dominating

them are different.

When the goals are different the memories are also likely to be different, as well as the reminding experiences. Thus, "checking on the competition" is a possible memory node, but it is not a MOP. Rather this is a TOP that would be grounded in MOPs (such as I-HEALTHCARE if the competition is a doctor).

"Spying" is thus a TOP and one might well be reminded of one spying experience while doing another. Feelings and attitudes, as well as goals and plans, contribute heavily to the formation of TOPs and the storage of episodes in terms of those TOPs as memories.

Furthermore, Grand Designs can relate to I-HEALTHCARE, if, dominating the I-MOP, are high level goals such as "running for president" or "marrying a beautiful girl". The interaction and interpretation of such I-MOPs in the service of high level goals create patterns for memories held at the TOP level.

Thus, a dentist visit could remind one of an abortive attempt at trying to gain power through looking good. It would do this by activating the TOP of which it was part. That TOP must have had in it the sequence of goals that we just mentioned. The reminding would take place by virtue of activating the I-MOP that related at the lowest level to that TOP. In other words, events are to MOPs as I-MOPs are to TOPs.

But, while we naturally process an input event in terms of the most relevant MOP we can find for it, processing to the TOP level is another matter. There is, in a sense, no correct TOP level interpretation of an input. Thus, POLITICS and PARRY are programs that, without having an explicit theory of TOPs, chose to process inputs in terms of certain TOP level structures. Finding communist takeover possibilities or instances of malevolence can be crucial to a mode of understanding. Thus, in an important sense, many different TOPs can be active at the same time in processing an input event. Seeing West Side Story can cause us to use the TOP involving the kind of plot in Romeo and Juliet as well as a TOP involving preventing juvenile delinquency and many others. All of these TOPs contain memories relevant to how we process an input and how we remember it. Thus, we can process the same input in many different ways at the same time. Each of these ways would correspond to some type of TOP level structure.

Finally then, we have the issue of the kinds of TOPs there are and how they are constructed and used. At the root of the solution to the problem of the kinds of TOPs there are is probably a well worked out goal taxonomy.

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REMINDING AND MEMORY ORGANIZATION: AN INTRODUCTION TO MOPS. (U)
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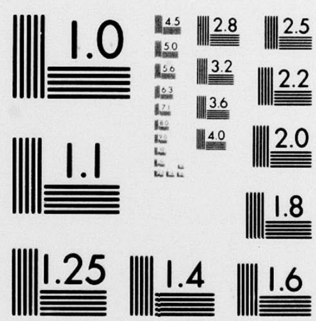
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15. Levels of Memory Revisited

In our earlier discussion we said that there were four memory levels: Intentional Memory (IM), Situational Memory (SM), Generalized Event Memory (GEM), and Event Memory (EM). We can now see that each of these levels of memory has a basic unit of high level structure as follow:

IM - I-MOPs

SM - MOPs

GEM - scripts

EM - unorganized events

But, we have also postulated a memory organized by TOPs. At the TOP level of organization (of what is, of course, essentially the same information simply organized differently), we have the same basic division amongst kinds of memories. Thus, the unorganized events of EM are getting organized by I-MOPs which get put together in terms of simple TOPs, such as Small Designs. This is done at what we call Goal-Based Memory (GBM). TOPs in GBM are organized by an even higher level of memory at which overall thematic reminding can take place. This memory, Thematic Memory (TM), is necessary in order to notice overall patterns such as that <u>West Side Story</u> is like <u>Romeo and Juliet</u>, or that a previous political ploy of the Russians "looks like" one the Germans used thirty years earlier. This high level thematic analysis, producing such structures as "unrequited love brings tragedy" is also an important part of memory, and hence processing to appropriate memory levels using TOPs is necessary for full

understanding, or understanding beyond the level of the initial input. It is this level of memory that helps us to draw new parallels and hence make new conclusions and generalizations. Thus TM accounts to some extent for our ability to learn.

Any input event can be processed and therefore remembered in terms of any and all of the levels of memory using any and all of the high level structures organizing information at that level. The advantage of all this is that memories can be excited in many possible ways enabling us to see things in many different lights and in terms of many different prior experiences. The price we pay is bad recall expressed by both memory confusions and lack of complete access.

16. Conclusion

The theory I have been trying to build here is an attempt to account for the facts of memory to the extent that they are available. In order to do natural language understanding effectively (whether by humans or machine) it is necessary to have as part of the working apparatus of such a system an episodic memory. Scripts and other higher level knowledge structures are not simply static data structures in such a memory. Rather they are both active processors and organizers of memory. Processing and storage devices must be the same in order to account for the phenomenon of reminding. In order to account for the fact that reminding and recognition confusions in memory both can be disembodied from large notions of a script to much smaller pieces, it was necessary to restructure our notion of a script to be much more particular. Full blown scripts of the kind SAM used would have to be reconstructed by memory. This reconstruction implies a subsequent decomposition. Thus, we can expect pieces of stories or experiences to be stored in different parts of memory, commonly with no link between them. The advantage of this set up is to understand more effectively the world around us. This more effective understanding manifests itself in better predictions about what will happen in particular well constructed experiences that have been built up over time. But, these predictions are only as good as the initial categorizations of the world that we make. Thus, an effective categorization of new experience is the major problem for an

understander as well as the major research problem facing those of us who work on understanding.

The negative effect of this breaking up of experience in order to make more effective predictions about the world is imperfect memory. People have imperfect memories because they are looking to make generalizations about experience that will serve as a source of useful predictions in understanding. That imperfect memory is a by-product of predictive understanding capabilities is a very important point for those of us working in computer modelling. I do not believe that there is any alternative available to us in building intelligent machines other than modelling people. People's supposed imperfections are there for a reason. It may be possible that in the distant future we will build machines that improve upon what people can do. But, they shall have to equal them first, and I mean equal very literally.

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